Author Affiliation:
Department of Electrical Electronics Engineering, University of Port Harcourt Nigeria

*Corresponding author
Department of Electrical Electronics Engineering, University of Port Harcourt
Nigeria
Email: ieukatu@gmail.com

Performance analysis of path loss models for digital terrestrial transmission in urban and rural environment.

Ifeanyi Emmanuel Ukatu[*], **Numbara Barineka Meneya**

ABSTRACT

This work shows the behavior of path loss models for Digital Terrestrial Transmission / Television (DTT) / (DTTV) in urban and rural environment. Path loss models such as: free space model, CCIR model, Hata Okumura model, Cost 231 Hata model and Egli models were compared and analyzed using MATLAB. The path loss value varies due to the change in distance between the transmitting point and receiving point. The simulation results indicate the best pick for both environments as Cost 231 Hata model, CCIR model and Egli model. Examining the outcome, Cost 231 Hata model outperforms in the urban environment while CCIR model can be regarded as the best model for the rural environment. This paper states the possibility of employing this when predicting signal losses in telecommunication.

Keywords: Path loss, Digital Terrestrial Transmission / Television (DTT) / (DTTV), Transmitter antenna height (Tah), Receiver antenna height (Rah)

1. INTRODUCTION

It is common in wireless communication to experience attenuation of signal quality while it propagates from a transmitting point to a receiving point. This can occur due to factors like the transmitter antenna height, transmission point operating frequency, transmitting power, distance, receiver antenna height etc (Ukatu, 2022). In a nut shell, Path loss can be described as the difference in signal quality between the transmitting point and the receiving point (Aymen Zreikat, 2017).

Progressing, a performance analysis will be carried out on various path loss models for different environment established by various researchers to identify the best path loss model suitable for digital terrestrial transmission (DTT).

The remaining part of the work is organized as follows: Section 2, describes various Propagation models. Section 3, provides the results and discussions. In Section 4, conclusion is presented followed by references in section 5.

2. PROPAGATION MODELS

Free Space Path loss

The attenuation of signal quality with no obstacle on a line-of-sight path is regarded as free space loss (Nafaa, 2014). Thus, the free space path loss is given as;

$PL^{fs} = 20Log10(d) + 20Log10(f) + 32.45$ (1)

Where, the signal frequency (f) in MHz, the distance (d) from the transmitter in Km and Path loss in dB.

CCIR OR ITU-R Path Loss Model

This model was formulated by the Comité Consultatif International des Radio-Communication (CCIR) currently known as the International Telecommunication Union for Radio communication (ITU-R) which is expressed as (Debus, 2006):

$PL^{ccir} = 69.55 + 26.16 \ Log10(f) - 13.82 \ Log10 \ (Tah) - CRah + [44.9 - 6.55 \ Log10(Tah)] \ Log10(d) - B$.   (2)

Where;

$CRah = [1.1 \ Log10(f) - 0.7] \ Rah - [1.56 \ Log10(f) - 0.8]$.
(2.1)

$B = 30 - 25 \ Log10(\% \ of \ area \ covered \ by \ buildings)$ (2.2)

Having, Tah as transmitter antenna height in meters, Rah as receiver antenna height in meters and CRah as the receiver antenna height correction factor.

HATA Okumura Path Loss Model

This model was formulated in 1980 and is a set of equation based on measurement and extrapolation from the curves derived by Yoshihisa Okumura. This model was designed for frequency range of 150MHz to 1500MHz, transmitter antenna height ranging from 30m to 200m, receiver antenna height from 1m to 10m and separation distance of 1Km to 20Km (Pardeep et al., 2014).

For Urban Terrain

$PL^{HO}urban = 69.55 + 26.16 \ Log10(f) - 13.82 \ Log10(Tah) - CRah + [44.9 - 6.55Log10(Tah)] \ *Log10(d)$
(3)

Where;

$CRah = 8.29[log10(1.54* \ Rah)]^2 - 1.1$ for $f \leq 300MHz$ (3.1)

$CRah = 3.2 \ [log10 \ (11.75 * Rah)]^2 - 4.97$ for $f \geq 300MHz$ (3.2)

For Suburban Terrain:

$PL^{HO}suburban = PL^{HO}urban - 2[log_{10} (\frac{f}{28})]^2 - 5.4$ (3.3)

For Open Rural Terrain:

$PL^{HO}rural = PL^{HO}urban - 4.78[log_{10}(f)]^2 - 18.33 * log_{10}(f) - 40.98$.   (3.4)

COST 231 Hata Model

This is an extension of Hata Okumura model which is used for propagation loss modelling in the frequency range of 1500MHz to 2000MHz. But due to the presence of correction factor and its simplicity, it may be used to predict path loss for frequency range greater than 2000MHz [5]. This model is equally a good fit for base station (transmitter) antenna height from 1m to 10m, Path distance from 1km to 20km and mobile station (receiver) antenna height from 30m to 200m (Chhaya et al., 2012).

Mathematical expressed as:

$PL^{CH} = 46.3 + 33.9 \ Log_{10} \ (f) - 13.82 \ Log_{10} \ (Tah) - CRah + [44.9 - 6.55 \ Log_{10} \ (Tah)] \ Log_{10} \ (d) + Cm$.
(4)

For Urban

$CRah = 3.20[Log10(11.75 * Rah)]^2 - 4.79$ for $f > 400MHz$ (4.1)

For Suburban and Rural

$CRah = [1.11 \ Log10 \ (f) - 0.7] * Rah - [1.5Log10(f) - 0.8]$ (4.2)

Cm is the correction factor (0dB for rural or suburban and 3dB for urban area)

Egli Path Loss Model
This model is designed for frequency range of 40MHz to 900MHz, and path distance from 0.1km to 60km. Egli path loss model was developed by Egli J.J on the basis of UHF/VHF TV transmission measured data in large cities. It is very suitable for irregular topography (Messaoud et al., 2017).
Mathematical expressed as:

$$PL^{EGLI} = 20 \log 10\ (f) + 40 \log (d) - 20 \log (Tah) + CRah \qquad (5)$$

Where;
$$CRah = 76.3 - 10 \log(Rah) \quad \text{for Rah} \leq 10m \quad (5.1)$$

$$CRah = 85.9 - 20 \log(Rah) \quad \text{for Rah} \geq 10m \quad (5.2)$$

3. RESULTS AND DISCUSSIONS

Data collected from Multichoice Nigeria (GOTV) was analyzed using Matlab. A comparison was done on different path loss model to ascertain the best choice for the urban and rural environment. The path loss models are: free space, CCIR, Hata Okumura, Cost 231 Hata and Egli models. From the figures, the best choices for both environments are Cost 231 Hata, CCIR and Egli Models. However, Cost 231 Hata model outperformed in the urban environment while for rural environment, CCIR model performed better.
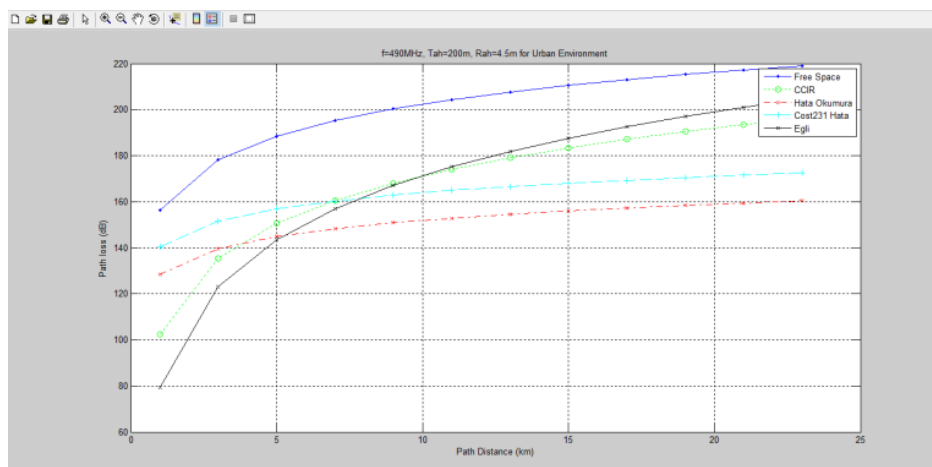

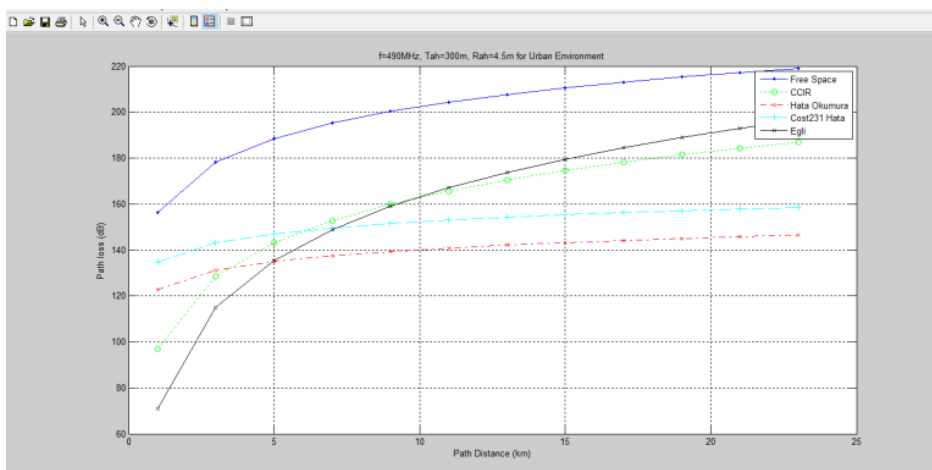**Figure 1** showing path loss vs distance at Rah 4.5m for urban environment.

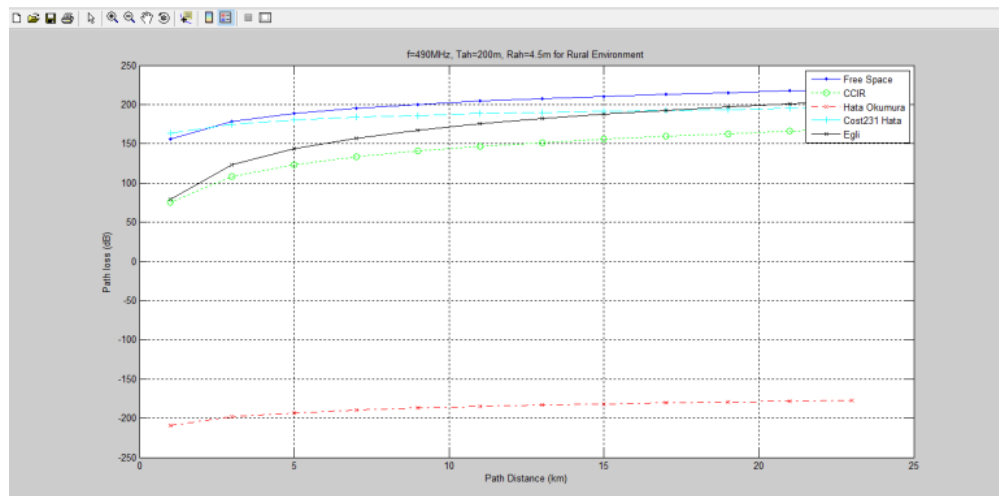**Figure 2** showing path loss vs distance at Tah 300m for urban environment.

Figure 3 showing path loss vs distance at Rah 4.5m for rural environment.
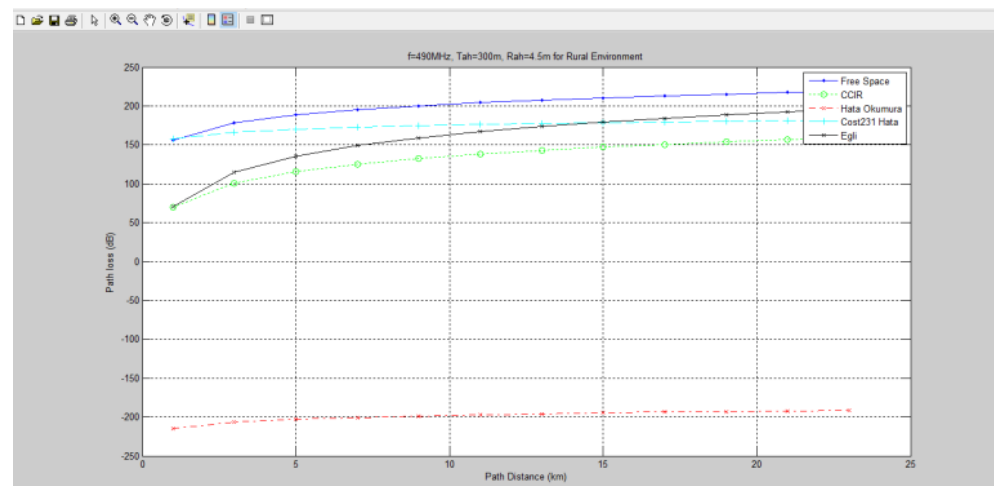

Figure 4 showing path loss vs distance at Tah 300m for rural environment.

4. CONCLUSION

In this paper, simulation results were showcased for various performance of path loss models for digital terrestrial transmission in Urban and rural environment. The simulation results were compared and analyzed based on the influence of transmitter antenna height and receiver antenna height over varying distance. Based on the simulation results, Cost 231 Hata model outperformed CCIR and Egli Models in the urban environment while for rural environment, CCIR model surpassed Cost 231 Hata and Egli Models.

Ethical issues

Not applicable.

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Conflict of Interest

The author declares that there are no conflicts of interests.

Data and materials availability

All data associated with this study are present in the paper.

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